



PHOTOVOLTAIC APPLICATION IN MODERN AGRICULTURE

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ABSTRACT

The use of photovoltaic (PV) electricity in modern agriculture has shown its advantages since the 1970s when it was possible to obtain a substantial green energy without the pollution by burning fossil fuels (coal, oil or natural gas) or the threaten of nuclear accident. Due to the price descent of the PV system, some new applications are becoming economically attractive, like the combination of PV and agriculture. Meanwhile, the use of agricultural soils contributes to making photovoltaic a low-cost energy generation source. Briefly, this combination can be a standby power or a direct injection to grid that is applied in a wide range of modern farming: irrigation, greenhouses and agricultural machinery. Therefore, the main aim of this study is to introduce these various applications of photovoltaics in modern agriculture.

Key words: *Solar energy, agriculture, PV, solar water pump*

INTRODUCTION

Since the birth of agriculture, it is closely bound up with sun or solar energy. And even long before the ancient human activities in agriculture, the nature has “processed” solar energy for billion years: plants and other photosynthetic organisms (e.g. phytoplankton) convert solar energy to food, which is the primary food resource.

However, agriculture activities were limited to the utilization of solar thermal energy until the first practical photovoltaic cell was publicly demonstrated on 25 April 1954 at Bell laboratories. The photovoltaic technology (PV), using photovoltaic cell converts solar energy to electricity in two steps: an electron-hole pair is generated once the cell absorbs light; and then, due to the structure of the device, the electronic and the hole are separated: the former to the negative terminal and the latter to the positive terminal (Tom Markvart, Luis Castañer).

Farmers have a profound emotion to the land, and they are willing to invest in renewable energy to protect the land, air and water from pollution, greenhouse gases (GHGS). PV technology supplies them a good alternative. In recent years, there is an emerging combination between agriculture and photovoltaic named agro photovoltaic (APV). This conception was promoted since 1980s and researchers have identified there is enough radiation underneath PV arrays to permit cultivation of many different crops (Goetz Berger A., Zastrow A.).

From the late 1960s, the U.S.S.R. started to install a variety of PV systems, ranging in capacity from 1 to 500 watts output for irrigation pumps, water gates, communication equipment and light buoy on waterways in its remote, semi-arid southeastern areas (H.S.Rauschenbach).

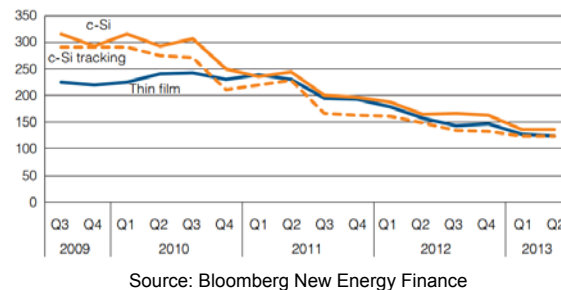
The 1970s energy crisis forced U.S. to found the U.S. Department of Energy with increasing funds, which applied much work to make large-scale PV utilization economically feasible. In 1977, an experimental PV plant system was completed that operated seasonally to power irrigation pumps, grain drying fans and other equipment (M.D. Pope et al.).

Solar energy is also an important part of energy structure of developing country now. As of 2000, there were more than 20000 water pumps are powered by PV notably in India, Ethiopia, Thailand, Mali, Philippines, and Morocco (Eric Martinot, Akanksha Chaurey).



Solar photovoltaic is experiencing a reduction in costs because of Feed-in tariffs (Fig1), contrary to the rising trend in the prices of electricity, oil and other fossil fuels. For the high-energy dependence area, especially in agriculture, like Spain, photovoltaic can efficiently relieve this plight without conventional resource.

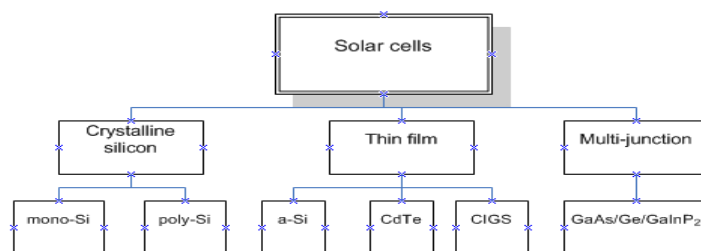
Fig.1. Levelized cost of PV electricity over time, developed market average (USD/MWh)



SOLAR CELLS CLASSIFICATION

Solar cells or photovoltaic cells are often named as an abbreviation of the semi conducting material they are made of (e.g. CdTe is the abbreviation of Cadmium Telluride). And according to the material, solar cells can be classified by three types: the first group is made of crystalline silicon, including monocrystalline silicon and polysilicon, has occupied more than half of worldwide PV production; the emerging thin-film cells, which include amorphous silicon, CdTe and CIGS (Copper indium gallium selenide) and also the dye-sensitized solar cells, are commercially significant in utility-scale photovoltaic power stations, building integrated photovoltaics or in small stand-alone power system; the third group is multi-junction solar cells. Due to their high efficiency and elevated price, they were designed for space application such as satellites and space exploration. However, now they are more and more applied in terrestrial concentrated photovoltaic (CPV). Because of lenses or curved mirrors with the high concentrate ratio, their efficiency can reach as high as 40% or more. The three groups of solar cells are illustrated in fig.2, and the features of commercial modules of crystalline silicon and thin film are shown in table 1.

Fig.2. classification of solar cells



SOLAR-POWERED PUMP

Solar-powered pumps (or photovoltaic pumps), using PV panels to generate electricity to power pumps, are very suitable for the pumps beyond the reach of power lines or just used for remote area water supply, livestock watering and small-scale crop irrigation (S.M.Ali *et al.*). They mainly contain four parts: PV panels, controller, pump and storage device. Their working process is shown in the Fig.3: the PV panels convert solar energy into DC(directing current) electricity with the help of the controller; then one part of the DC electricity powers the pump directly, which is very common in the applications such as



garden fountains, landscaping, drinking water for livestock, or small irrigation projects; whereas the other part is either stored in a battery or converts to AC (alternating current) which is suitable for larger irrigation system by an inverter.

Table1.Features of commercial modules of crystalline silicon and thin film

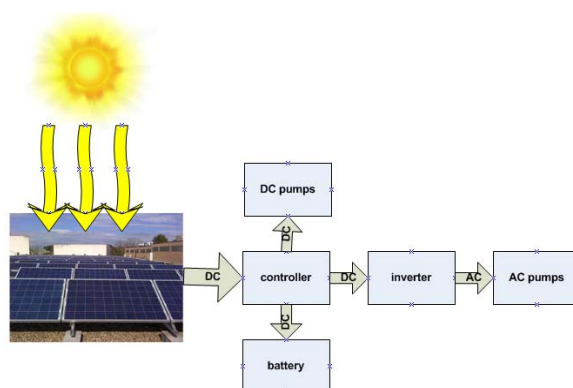
	Crystalline silicon	Thin film
Market share	80%	Less than 20%
Efficiency	12%-20%	3%-11% ¹
Power decline	~1%/year	Initial 20%, 1%/year ²
Performance guaranty	25-30years	20-25years
Encapsulation	Tempered glass	Untempered glass
Voltage	Low	High
Temperature coefficient ³	~-0.5%/K	~-0.2%/K
Price	high	low
Other	Non-toxic	Flexible, better performance in cloudy condition

¹Some CdTe and CaAs Thin film modules can reach the efficiencies above 20% (Martin A. Green *et al.*)

²For amorphous silicon, there is a 20% initial power decrease and followed by 1% annual decrease.

³Temperature coefficient mainly includes three types: temperature coefficient of open-circuit voltage, short-circuit current and maximum power, here refers to the temperature coefficient of maximum power

Fig.3. Working process of solar-powered pump



For solar-powered pumps, the polycrystalline silicon is the primary choice. Because its higher efficiency contributes to less area be occupied. On the other hand, it performs better in sunny weather when the need for water is greater, whereas thin film modules are better in cloudy weather. For instance, in china, it could create a 400GW installed capacity even only 1% of the arid area employs this solar-powered pump technology, and 1GW capacity is able to water 3000km² ~6000km² area.

AGRO PHOTOVOLTAIC

Agro photovoltaic greenhouse integrates photovoltaic, intelligent control and modern farming (fig.4). This combination of agriculture and photovoltaic creates a new “farming inside, power generation outside” scenario: the electricity generated by the photovoltaic panels can light the greenhouse plants or even the sunshine can pass through some transparent thin film modules, and also the electricity can power the agricultural equipment like pumps, during the cold season supplies heating to the greenhouse and



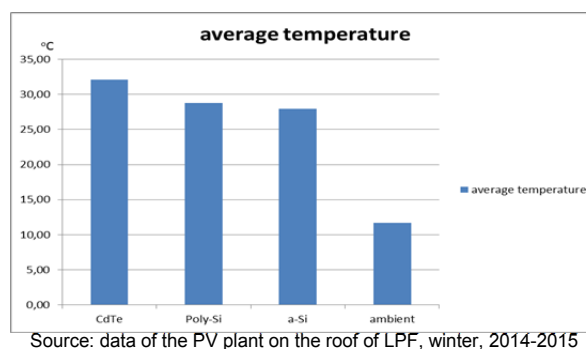
control the temperature, promotes the rapid growth of crop. In a similar way, there is also a combination of fishery and photovoltaic.

Fig.4. Pu Dong Hua Shen photovoltaic farm, Ji Mo, Shan Dong, China



Agro photovoltaic solves two problems simultaneously: agriculture can supply the vast farm land to photovoltaic which is an area-consuming project; in return, photovoltaic provides the essential power to agriculture. Biomass and electricity are generated at the same time (M. Beck *et al.*). Due to the vast farm land and lower cost, thin film modules can be installed as the primary choice. Additionally, PV modules do not generate electricity and also produce much heat simultaneously. As shown in graph1, the temperature is somewhat higher (20-30°C) than the ambient; it could be an additional heating source for the greenhouse.

Graph1. Comparison of module temperature and the ambient



CONCLUSION

At the time of the lack of traditional fossil energy, harsh geographical conditions' requirements of wind energy and hydro energy and safety consideration of nuclear energy, PV provides an energy guaranty for modern agriculture. PV is similar to agriculture, where both are "farming" the sun: the former produces electricity and the latter results in food. The combination of PV and agriculture gives birth to plenty of applications: solar-powered pump, agro agriculture, agro fishery and so on.

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